SciDAC Visualization and Analytics Center for Enabling Technologies
Semi-Annual Progress Report
April 2008 through September 2008

E. Wes Bethel[*] and Chris Johnson[†]
Principal Investigators

Charles Hansen, Valerio Pascucci, Claudio Silva, Allen Sanderson [‡]

Sean Ahern, George Ostrouchov, Dave Pugmire, Jeremy Meredith[§]

Hank Childs, Peer-Timo Bremer,
Daniel Laney, Ajith Mascarenhas, Kathleen Bonnell[¶]

Ken Joy, Christoph Garth, Bernd Hamann[‖]

Gunther Weber, Prabhat, Oliver Rübel, Cecilia Aragon[**]

October 1, 2008

[*] Lawrence Berkeley National Laboratory
[†] Scientific Computing Institute, University of Utah
[‡] Scientific Computing Institute, University of Utah
[§] Oak Ridge National Laboratory
[¶] Lawrence Livermore National Laboratory
[‖] University of California – Davis
[**] Lawrence Berkeley National Laboratory

Contents

1 Executive Summary

The SciDAC Visualization and Analytics Center for Enabling Technologies (VACET) focuses on leveraging scientific visualization and analytics software technology as an enabling technology for increasing scientific productivity and insight. Our mission is to foster scientific insight through creating and deploying effective data understanding technology that is truly responsive to the needs of our stakeholders in the scientific research community who are “awash in data.” It is widely accepted that one of the bottlenecks in contemporary science is the need to gain insight from vast collections of complex data.

The vision for our Center is to respond directly to this challenge by adapting, extending, creating when necessary and deploying visualization and data understanding technologies for our science stakeholders. Organized as a Center for Enabling Technologies, we are well positioned to be responsive to the needs of a diverse set of scientific stakeholders in a coordinated fashion using a range of visualization, mathematics, statistics, computer and computational science and data management technologies.

We are pleased to report accomplishments during the period of April 2008 through September 2008, both in terms of impact for scientific stakeholders and in terms of providing leadership in the visualization and analysis community.

VACET has made a substantial impact on the SciDAC community:

-
- .
-
-
-

VACET continues to set the standard for visualization research productivity, outreach, and service:

- Publications: we report 28 peer-reviewed journal articles, 13 peer-reviewed works that appear in our field’s leading conferences, several invited articles, book chapters, technical posters and technical reports (see Section 5.1.
- Invited presentations: we have delivered approximately twenty different invited presentations (Section 5.2).
- Software Tutorials: our team has delivered five tutorials on use and application of VACET software to scientific stakeholders (Section 5.3.)
- Workshop participation: VACET has contributed to five different domestic and international workshops on topics ranging from high energy fusion to mathematics for petascale data (Section 5.4).
- Awards. VACET wins three (of ten) “People’s Choice Awards” at the SciDAC 2008 Program meeting in Seattle, WA (Section 5.5).
- Service. VACET researchers have served as technical reviewer for six different journals, conferences and funding programs; and served on the Program Committee (or as general chair or co-chair) for 26 different technical conferences and symposia (Section 5.6).

VACET also has been laying the groundwork for future results, both in terms of visualization research and in terms of deploying technology to our stakeholders:

- Streamlines. We have developed and deployed a parallel capable “streamlines engine” that will address needs from multiple science stakeholders (combustion, fusion, combustion, turbulence, astrophysics). This important new capability, described in Section 4.1, will help scientists gain deeper understanding into complex, time-varying and multi-grid vector field data produced by large-scale simulations. This work is an excellent example of VACET research, development and deployment being driven by science stakeholders’ needs.

- Embedded Boundary/Material interfaces. Recent research has produced a highly accurate technique for computing embedded boundaries/material interfaces from simulation data containing cells with volume fraction data. The need to compute and display such interfaces is high on the priority list of one of our stakeholders, APDEC. While we have recently deployed legacy code that computes and displays embedded boundaries, we are working towards deploying the new Active Interface technique in VisIt, our production visualization application (see Section 4.2), and extending it to work with data on AMR grids.

2 Specific Stakeholder Projects

2.1 Accelerator Modeling: Using Analysis to Identify Beam Particles

The scientific stakeholders on this effort[1] are both experimentalists and computational scientists. The primary objective for this project is to devise a mechanism for automatically finding particles that are undergoing acceleration in a laser-wakefield simulation dataset. This capability would help to automate a process that is currently performed manually. In the long run, this capability will certainly help to accelerate data understanding. As it evolves, this technique will likely be integrated with other tools (e.g., high performance visual data analysis) as part of a broad set of HPC tools for scientific knowledge discovery in accelerator science.

Accomplishments

We devised a methodology for automatically identifying beam particles, ie., those undergoing wakefield acceleration, from data produced simulation:

- The methodology identifies ”bunches” of particles likely to be part of the beam as those having both high momentum and are in close spatial proximity.

- For each bunch of particles from all timesteps’ worth of data, we use a graph algorithm to track bunch movement and evolution across timesteps.

- Separately, we use fuzzy clustering to classify particles as either “beam” or “non-beam,” where classification is continuous rather than discrete.

- Results of fuzzy clustering are compared with those from the space/momentum classification stage. Where there is agreement between these two models, we have a high quality beam.

[1] C. Geddes and E. Cormier-Michel (LBNL), P. Messmer (Tech-X) are INCITE awardees at NERSC and part of the SciDAC COMPASS project.

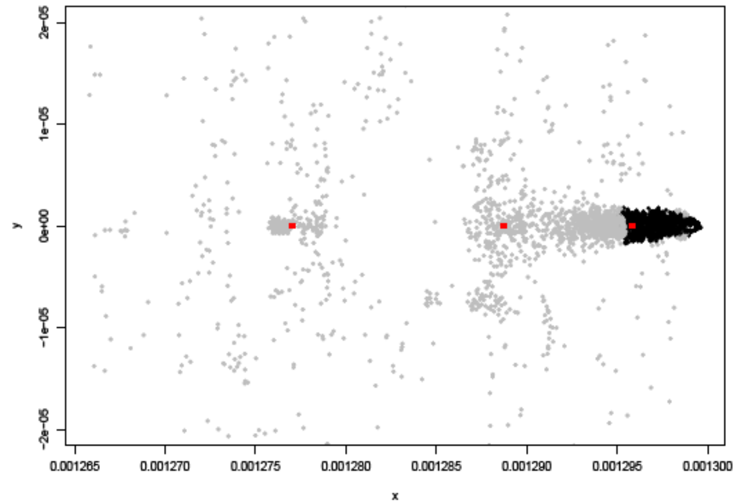


Figure 1: Beam-point candidates combined with fuzzy clustering. Beam points, which are comprised of high-momentum particles having spatial coherence are shown in red. The results of fuzzy clustering shows beam particle candidates in black, and non-beam particles in gray.

Future Work

- Further work in refining our ability to perform unsupervised classification of beam particles.
- Explore use of parallel analysis techniques, eg., Parallel R in conjunction with our colleagues at ORNL.
- Since the work thus far focuses exclusively on particles, and ignores the other available data (e.g, electric field), longer term work will focus on devising the methodology to better understand the relationship between particles undergoing acceleration and their surrounding environment.

3 Common Infrastructure Projects

3.1 High Quality Volume Rendering

This ongoing project aims to perform "technology transfer," where we perform the software engineering necessary to transition a research prototype code into a form suitable for production deployment in VisIt, our production visualization application. This project, which involves VACET personnel from Utah, LLNL, and ORNL, is a successful example of focusing software engineering effort to bring a successful research prototype into production use. The technology in question is SLIVR: the SCIRun Library for Interactive Volume Rendering[2]

Accomplishments

- SLIVR is now completely integrated into VisIt. The additions currently reside in the development trunk of VisIt, and are expected to ship with the upcoming 1.11 VisIt release. Examples

[2]See `http://slivr.sci.utah.edu`.

images show SLIVR applied to 3D medical data (Figure 2) and the GUI for multi-dimensional transfer functions (Figure 3).

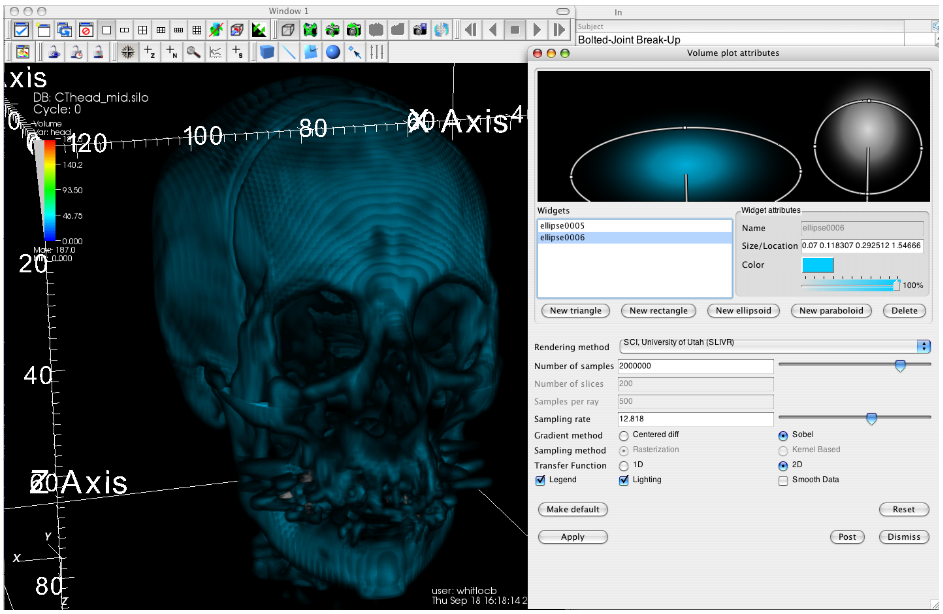


Figure 2: SLIVR is now integrated in VisIt and appears as one of its volume rendering options.

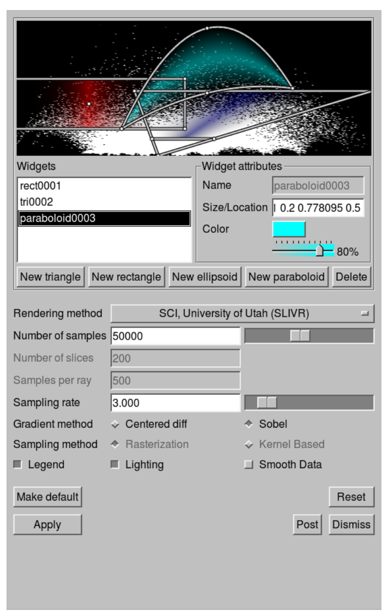


Figure 3: SLIVR provides a scalar magnitude/gradient 2D histogram and a variety of idgets to control rendering operation.

Future Work

4 Technology Incubation Projects

4.1 Streamlines

A long-standing gap in visualization technology in general, and the VACET technical portfolio in particular, is the computation of streamlines in parallel and on multi-grid domains. Recent work has produced a production-quality, parallel capable "streamlines engine" that meets multiple VACET science stakeholder needs as well as makes a novel contribution to the field of high performance visualization. The new parallel-capable, multi-grid aware streamlines engine has been deployed in VisIt (version 1.10), VACET's production-quality parallel-capable visual data analysis software infrastructure.

Science Stakeholders

VACET is working with the following stakeholders, all of whom have requested and stand to benefit from parallel and multi-grid streamlines: (1) Phil Colella (LBNL) of the SciDAC Applied Partial Differential Equations Center (APDEC); (2) John Cary (Tech-X) of the SciDAC Science Application "Framework Application for Core-Eedge Transport Simulations" (FACETS); (3) Steve Jardin and Stephane Ethier (PPPL) of the SciDAC Center for Extended Magnetohydrodynamic Modeling (CEMM); (4) Don Batchelor (ORNL) of the SciDAC Science Application "Simulation of Wave Interactions with Magnetohydrodynamics" (SWIM); Johan Larsson and Sanjiva K. Lele (Stanford) of the SciDAC Science Application "Simulations of Turbulent Flows with Strong Shocks and Density Variations." Although we have had direct contact and requests with these specific SciDAC projects, virtually all our stakeholders will stand to benefit from this technology.

Science Stakeholder Needs.

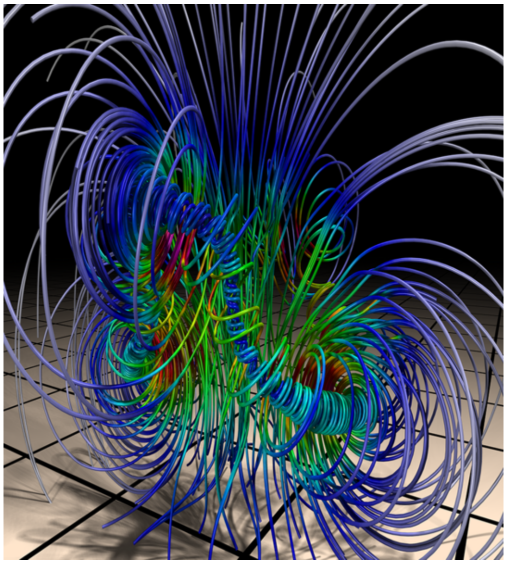
1. AMR/multi-grid domains. Streamlines computation consists of integrating a path tangent to a vector field. Traditionally, these algorithms assume a single domain, and they do not accomodate the boundary conditions that occur at coarse/fine grid boundaries in AMR datasets. These boundary conditions impose special challenges: (1) streamline algorityhms do not understand nesting of patches, and do not accommodate the transition from finer patches from coarser patches; (2) the resulting streamlines do not have the desired level of continuity across grid boundaries; (3) there is little information as to streamline quality in general and in particular when streamlines cross patches.

2. Poincaré plots. This type of visualization (see Figure 4) is useful in fusion to quickly visually identify magnetic "islands" in the plasma core.

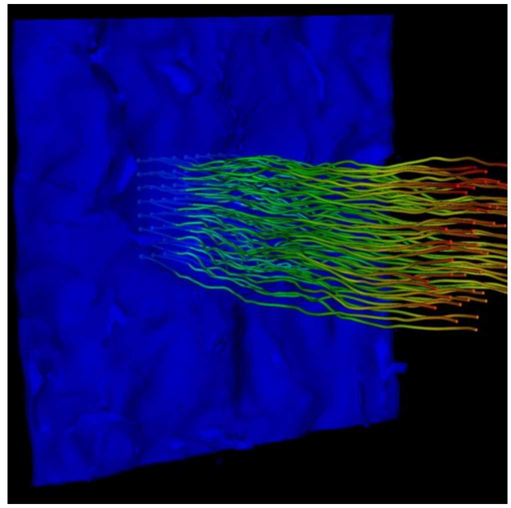
3. Parallel Performance. The long-term objective is to leverage parallel computing platforms to accelerate streamlines computation and to accommodate ever-large datasets.

4. Pathlines. Accurate streamline computations across timesteps.

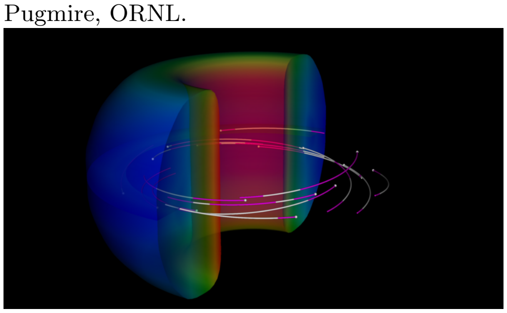
5. Support for additional/custom Initial Value Problem (IVP) solver types with advanced features (e.g. continuous output), etc.



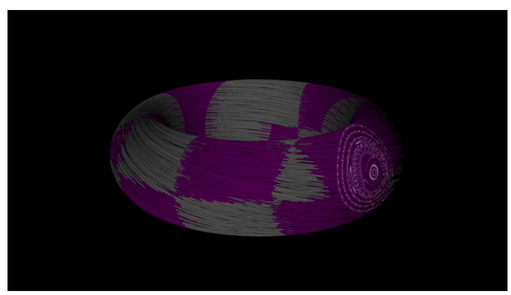
(a) Two merging vortex cores computed by the APDEC/Chombo code. VisIt computes the streamlines from the AMR dataset, then we render them with an off-the-shelf raytracing (photorealistic) software application. Dave Pugmire, ORNL.



(b) Image produced by Dave Pugmire and Sean Ahern (ORNL) for the SciDAC "Shocks" Center.



(c) Seeds placed randomly within the tokomak are used for streamline generation.



(d) Poincaré plot of randomly seeded streamlines in data produced by a fusion tokomak simulation.

Figure 4: These images show application of the VACET streamlines engine to data from different science domains: combustion (upper left), shock physics (upper right), and fusion (lower left and right).

Accomplishments this Period.

1. Introduce new IVP solver class hierarchy into VisIt with the aim of implementing individual IVP schemes as subclasses.
2. Incorporate several integration schemes such as RKF45 and DOPRI56 (and possibly tie in IVP libraries such as CVODE).
3. Introduce streamline (convenience) class more specifically aimed at streamline integration requirements (i.e. construction and storage of a global IVP solution) and a matching datatype to pass streamline sets between VisIt filters and plugins.
4. Parallelize IVP solver and streamlines.
5. Implement and evaluate parallel streamline algorithms.
6. Adapt streamline integration to multiblock datasets.
7. Deploy in VisIt version 1.10 (See Figure 4).

Future Goals.

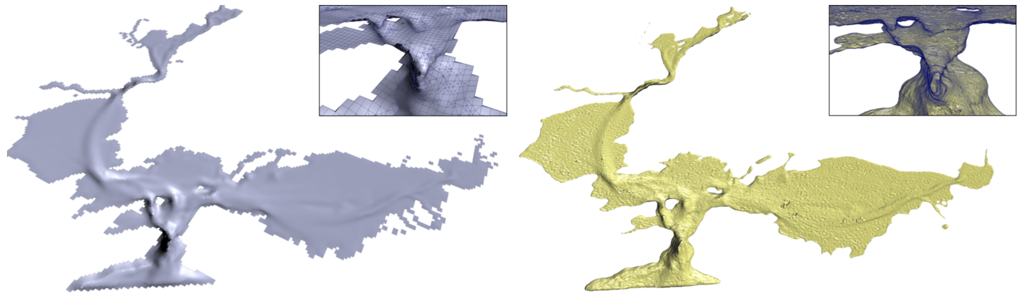
1. Parallel Performance. While we have an initial prototype in production, we would like to better understand and characterize its performance. Since there exists no prior work in this area, we expect significant results: one or more major publications, benefit to our science stakeholders.
2. AMR streamlines. While our initial implementation is multi-block aware, a good deal of work remains: (1) continuity at and across coarse/fine grid boundaries; (2) comparison of different interpolation basis functions; (3) evaluate alternatives using objective error metrics.
3. Apply the streamlines engine to science problems (e.g., Poincaré analysis).

4.2 Embedded Boundary/Material Interface

In many applications it is necessary to reconstruct or track the boundary surfaces, or "interfaces," between multiple materials that commonly result from multi-fluid Lagrangian-Eulerian hydrodynamics calculations. This problem, where the generated data sets have the characteristic that each cell contains a "fraction" representing the percentage of each material contained in the cell, now arises in a variety of applications, and is frequently called the **embedded boundary problem**. The challenge is to utilize the material fractions in each cell to reconstruct the boundaries between materials. VACET researchers have been developing a number of possible solutions to this problem.

Having a production-quality solution to this problem will allow one of our primary stakeholders and his team (Colella/APDEC) to completely adopt VisIt for their visual data analysis infrastructure. The benefit to their team is a substantial cost savings – they will no longer have to create, update and maintain their own code base for visual data analysis.

We expect to develop a number of solutions to this problem. We do not expect that any one algorithm will complete solve this problem, but that we must produce a number of solutions that can impact our stakeholders. There are several problems that must be solved: (1) the interface reconstruction method must produce interfaces that preserve the given volume fractions, (2) the solution must be scalable, (3) the solution must be computationally "quick," and (4) adaptive techniques must be developed that can be tailored to the user's requirements. We will implement this into VisIt to get the maximum impact with the scientists.



(a) San Francisco Bay bottom using legacy VisIt implementation of material interfaces.

(b) San Francisco Bay bottom using new material interface methods.

Figure 5: Comparison of legacy (left) and new (right) techniques for computing embedded boundaries.

Accomplishments this Period

1. We have developed a new adaptive that utilizes an active interface method to adjust an initial approximation of the interface to one that matches given volume fractions (see Figure 5. This allows us to separate the problem into two components: a topology-generator that develops a plausable topology for the interface reconstructions – from this we can generate an approximate interface – and an iterative system that adjusts this initial approximation to match the given volume fractions.

2. A paper has been submitted on this new algorithm as John Anderson, Christoph Garth, Mark A. Duchaineau and Kenneth I. Joy, "Smooth, Volume-Accurate Material Interface Reconstruction," submitted to IEEE Transactions on Visualization and Computer Graphics, September 2008.

3. We have developed an initial approximation method based on a "Potts" Model. This allows us to generate interfaces that reflect some fine detail in the scene.

4. The Potts model topology generator has been published as John Anderson, Christoph Garth, Mark A. Duchaineau and Kenneth I. Joy, "Discrete Multi-Material Interface Reconstruction for Volume Fraction Data," Proceedings of the European Visualization Conference, Computer Graphics Forum, Vol. 27, No. 3, 2008, 1015-1022.

5. We have implemented earlier material interface codes (e.g., PLIC) in VisIt for our APDEC Stakeholders.

Future Work

1. Implement the new Active Interface method into VisIt.

2. Develop an AMR version of the Active Interface method that can be used by our APDEC collaborators.

3. Develop a multiresolution version of the Active Interface algorithm.

4. (Longer term: fully implement these algorithm into VisIt, develop a method for unstructured meshes (the topology generator is the difficult component here), and develop the level-set

method. Each of these project have been started, and some preliminary results have been obtained. However, we expect this project, and its ”spin-offs to be active during the entire VACET project.

4.3 Uncertainty Visualization

Towards the Visualization of Multidimensional Probabilistic Distribution Data

Uncertainty information is an important characteristic associated with much of the data scientists encounter. Such information is typically included with the data as 2D charts and graphs, however incorporating uncertainty into visualization techniques has proved quite challenging. Recent work examines a class of uncertainty data that is characterized as a set of probability density functions (PDFs) defined across a triangular mesh, and explores ways at visually presenting this data.

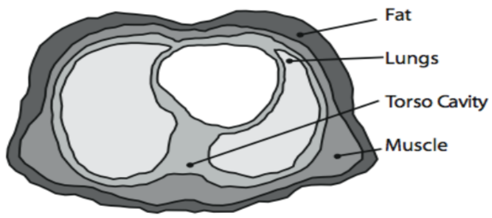
The data used in this work comes from the sensitivity analysis electrical conductivity within computational models of bioelectric fields of the heart. Such an approach quantifies the sensitivity of the electrocardiographic forward problem by creating a mathematical model to reconstruct a biological experiment in which the voltages on the human torso are estimated based on the input electrical conductivities (from previous work). The simulation stochastically varies the input conductivities of different tissues such as fat, lungs, or muscle and examines the resulting changes in potential across the torso.

Our recent visualizations strive to investigate the complex sensitivity analysis data. The data is defined on the classified torso mesh (shown below in Figure 6). The mean and standard deviation of the data are shown colormapped onto the torso data space, and the first approach we explore is to combine the mean and standard deviation into a single visualization. We achieve this by simply encoding the mean into a heightmap, and colormapping variance onto this map. This provides for a simple way to show two variables of the dataset, and quickly find locations of large and small average values of the data, as well as high variance values.

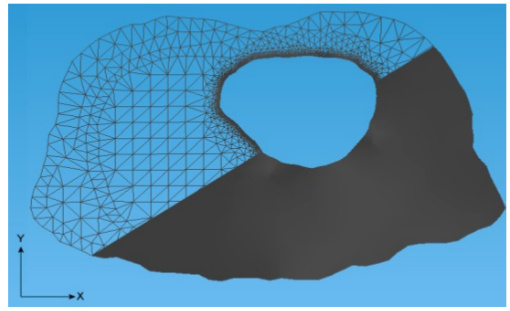
The next approach we investigate is to create a volume by stacking the output potentials for every input conductivity. This volume can be volume rendered, or iso-surfaced. The structure of the iso-surface is of most interest. An iso-surface that falls straight down indicates the potential at this point in 2D space does not vary when changing; thus, it is considered independent at that point. A bending iso-surface indicates areas of high dependence on the input conductivity. We can also see that even in the region with the highest variance only small conductivities result in potential changes. This relationship becomes visible using our new visualization technique (Figure 7).

Visualizing Summary Statistics and Uncertainty

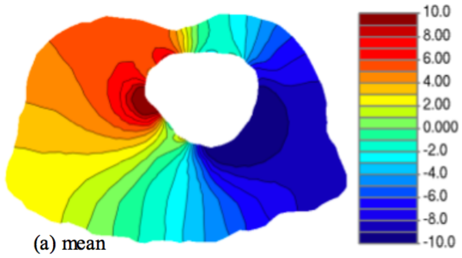
An important visualization research problem is to effectively convey uncertainty information along with traditional visual data representations. Recent work investigates the problem from a graphical data analysis standpoint. By using descriptive statistics to summarize both characteristic features of a data distribution and measures of uncertainty, we can achieve a more cohesive understanding of the information. In this work, we reexamine the box plot and its relatives and develop a new hybrid summary plot that combines moment, cumulant, and density information along with higher order descriptors that rely on distribution fitting. In view of the important role summarizing plots has in decision making, our work focuses on using advanced visualization techniques to incorporate additional descriptive parameters, while simultaneously improving the comprehensibility of summary plots.



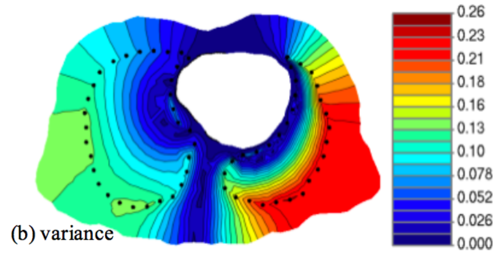
(a) The classified human torso.



(b) The torso mesh space.



(c) Mean colormapped onto the torso.



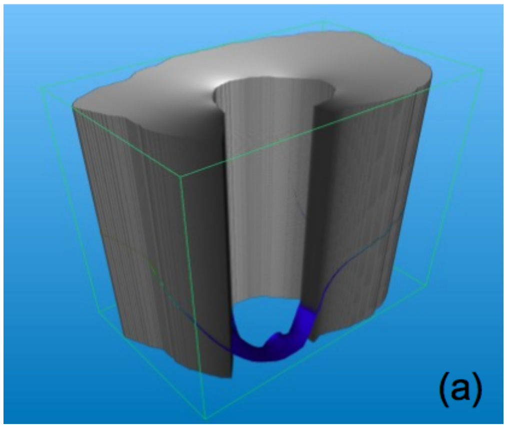
(d) Standard deviation colormapped onto the torso.

Figure 6: Comparison of legacy (left) and new (right) techniques for computing embedded boundaries.

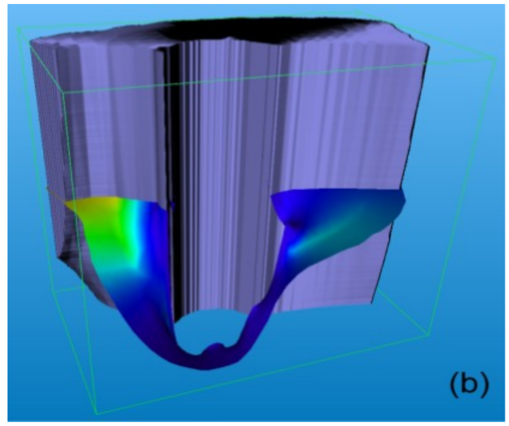
The approach this work takes to understand and visualize uncertainty data focuses on methods for quantitatively displaying the underlying statistics which describe the uncertainty of a dataset. The measures typically used to define uncertainty are mean and variance (standard deviation) and many methods exist in graphical data analysis packages for displaying these quantities. This work extends these methods to include other descriptive statistics as well as distribution fitting techniques to not only provide visualizations of uncertainty, but also give the user a way to better understand the data distribution. Techniques for visualizing the correlation between multiple 1D categorical dataset are also presented (Figure 8), along with a variety of exemplar datasets.

Summer 2008 Internship

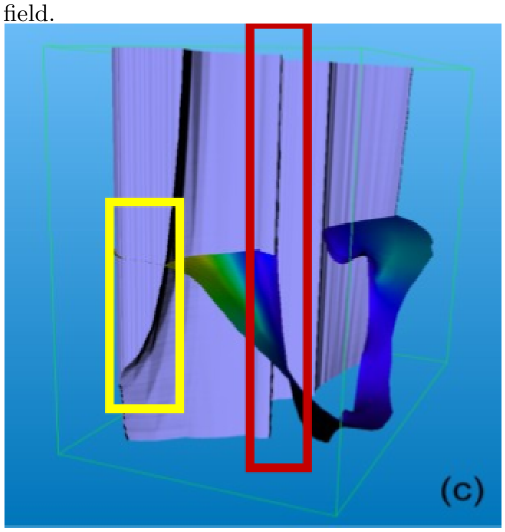
Kristi Potter (Utah) worked at Sandia over the summer, continuing research on uncertainty visualization. The main thrust of this work was to incorporate scientific and information visualization methods into a single system to provide an investigational tool for data exploration. The main focus of the work was on Ensemble data from NOAA, specifically short-term forecast data (SREF), consisting of multiple forecast models run using a variety of input perturbations and forecast hours. The biggest challenges of this work are in the complexity of the data; the numerous variables, simulation hours and input perturbations inhibit the direct display of the data and require filtering of some type to intelligibly display. However, the aim of the system is to provide a tool for both hypothesis forming and testing, thus the user must be able to drive the visualization system based to further the exploration of the data. As such, the prototype created over the summer provides a global overview of the data in the form of mean and variation of a specific, user-chosen variable, along with an interactive "drill-down" which shows the actual data values which contribute to the global presentation. The prototype was fully implemented in VTK. Continuing work will extend



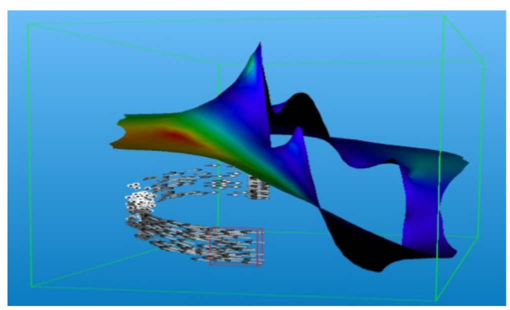
(a) Direct volume rendering of the potentials volume superimposed onto the mean height-field.



(b) Isosurfacing the potentials volume.

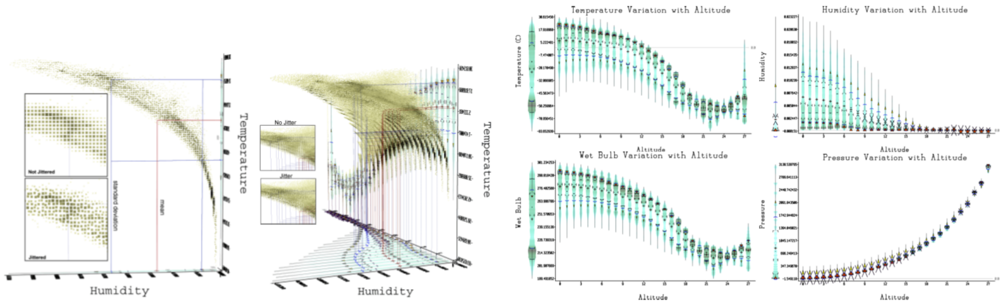


(c) Iso-surfacing of the potentials data. Bends in the iso-surface (yellow box) show areas with high dependence on the input conductivity.



(d) Particle tracing on the potentials volume.

Figure 7: These images show the results of recent research in the field of uncertainty quantification and visualization.



(a) Joint mean (red lines), joint standard deviation (blues lines) and the joint histogram for a single (left) and multiple (right) categorical datasets.

(b) Temperature, humidity, wet bulb, and pressure data taken at a singlemoment in time across the world. Data courtesy of the Canada Meteorological Centre.

Figure 8: Visualizing statistics using different new techniques.

this approach to other datasets as well as investigate improved visualization techniques.

Future Work

- Research on Direct High Dimension Probabilistic Data Visualization with applications in fusion simulation and biophysical phenomena. Mathematical models used for the reconstruction of experimental results, can produce data distributions with spatial positions in 2 and 3D. These distributions not only express the results of the model, but also fully describe the uncertainty of the results. While much uncertainty visualization research has focused on scalar, or possibly vector values quantifying uncertainty, visualization techniques which expose the entire distribution can lead to a more through understanding. However, the dimensionality of this dataset is too large to be directly displayed or easily comprehended, thus techniques for displaying this data are very important.

- Development of general methods for uncertainty visualization in scalar and vector valued datafields. Most visualization techniques that incorporate uncertainty information treat uncertainty like an unknown or fuzzy quantity. These methods employ the syntax of the word uncertainty to create the interpretation of uncertainty or unknown to indicate areas in a visualization with less confidence, greater error, or high variation. Blurring or fuzzing a visualization, while accurately expressing the lowered confidence one should have in that data, does not lead to a more informative decision making tool, but instead obfuscates the information that lead to the measure of uncertainty. Such a solution to the problem of adding qualitative information to visualization does not elucidate on the quantitative measures leading to the uncertain classification, and thus is missing some important information. The goal of this work is to identify and visualize the measures typically thrown under the umbrella of uncertainty. Uncertainty, as the scientific visualization field titles it refers to quality of a measured value and can include measures of confidence, error, and deviation. Statistically, uncertainty is harder to identify, since there are many measures that can add to the qualification of data. Using measures that are statistically meaningful to express the uncertainty in a data set exposes insights to the data that may not have previously been obvious. Adding such quantities to visualizations will improve the effectiveness of visualizations by providing a more complete description of the data, and create better tools for decision making and

analysis.

- Continue collaboration with Sandia National Lab on the visualization of ensemble datasets. Ensemble datasets consist of multiple mathematical models which predict the result of a simulation. Uncertainty is inherit in these datasets, since the result of each model varies. In addition, sensitivity analyses are often incorporated into the ensembles. Not only is the data itself complex to visualize, the uncertainty associated with this data is of utmost importance. In the upcoming 6 months work will continue on the prototype built in collaboration with SNL to visualize ensemble data, resulting in a submission to the IEEE Visualization conference.

5 Publications, Presentations, Awards, Service, and Outreach

5.1 Publications

5.1.1 Peer-Reviewed Journal Articles

1. Luke J. Gosink, John C. Anderson, E. Wes Bethel, and Kenneth I. Joy. Query-Driven Visualization of Time-Varying Adaptive Mesh Refinement Data. *IEEE Transactions on Visualization and Computer Graphics (Special Issue: Proceedings of IEEE Visualization 2008)*, 14(6), November/December 2008. LBNL-803E.

2. Oliver Rübel, Gunther H. Weber, Min-Yu Huang, E. Wes Bethel, Mark D. Biggin, Charless. C. Fowlkes, C. Luengo Hendriks, Soile. V. E. Keränen, Michael B. Eisen, David W. Knowles, Jitendra Malik, Hans Hagen, and Bernd Hamann. Integrating data clustering and visualization for the analysis of 3d gene expression data. *IEEE Transactions on Computational Biology and Bioinformatics*, 2008. LBNL-382E, to appear.

3. C. Scheidegger, J. Schreiner, B. Duffy, H. Carr, and C. Silva. Revisiting Histograms and Isosurface Statistics. *IEEE Transactions on Visualization and Computer Graphics (Proceedings of IEEE Visualization 2008)*, 14(6), 2008.

4. C. Dietrich, J. Comba, L. Nedel, C. Scheidegger, and C. Silva. Edge Groups: A New Approach to Understanding the Mesh Quality of Marching Methods. *IEEE Transactions on Visualization and Computer Graphics (Proceedings of IEEE Visualization 2008)*, 14(6), 2008.

5. D. Koop, C. Scheidegger, S. Callahan, J. Freire, and C. Silva. VisComplete: Data-driven Suggestions for Visualization Systems. *IEEE Transactions on Visualization and Computer Graphics (Proceedings of IEEE Visualization 2008)*, 14(6), 2008.

6. R. M. Kirby and C. Silva. The Need for Verifiable Visualization. *IEEE Computer Graphics and Applications*, 2008.

7. J. Daniels, C. Silva, J. Shepherd, , and E. Cohen. Quadrilateral Mesh Simplification. *ACM Transactions on Graphics (Proceedings of SIGGRAPH Asia 2008)*, 2008.

8. J. Daniels, T. Ochotta, L. Ha, and C. Silva. Spline-Based Feature Curves from Point-Sampled Geometry. *The Visual Computer*, 24(6):449–462, 2008.

9. A. Baptista, B. Howe, J. Freire, D. Maier, and C. Silva. Scientific Exploration in the Era of Ocean Observatories. *Computing in Science and Engineering*, 10(3):53–58, 2008.

10. J. Freire, D. Koop, E. Santos, and C. Silva. Provenance for Computational Tasks: A Survey. *Computing in Science and Engineering*, 10(3):11–21, 2008.

11. E. W. Anderson, J. Ahrens, K. Heitmann, S. Habib, and C. Silva. Provenance in Comparative Analysis: A Study in Cosmology. *Computing in Science and Engineering*, 10(3):30–37, 2008.

12. L. Bavoil, S. Callahan, and C. Silva. Robust Soft Shadow Mapping with Depth Peeling. *Journal of Graphics Tools*, 13(1):19–30, 2008.

13. C. Scheidegger, D. Koop, E. Santos, H. Vo, S. Callahan, J. Freire, and C. Silva. Tackling the Provenance Challenge One Layer at a Time. *Concurrency And Computation: Practice And Experience*, 20(5):473–483, 2008.

14. S. P. Callahan, J. H. Callahan, C. E. Scheidegger, and C. Silva. Direct Volume Rendering: A 3D Plotting Technique for Scientific Data. *Computing in Science and Engineering*, 10(1):88–92, 2008.

15. C. Silva and J. Tohline. Guest Editorial: Special Issue on Computational Provenance. *Computing in Science and Engineering*, 10(3):9–10, 2008.

16. Gunther H. Weber, Oliver Rübel, Min-Yu Huang, Anagla H. DePace, Charless C. Fowlkes, Soile V.E. Keränen, Cristian L. Luengo Hendriks, Hans Hagen, David W. Knowles, Jitendra Malik, Mark D. Biggin, and Bernd Hamann. Visual Exploration of Three-dimensional Gene Expression using Physical Views and Linked Abstract Views. *IEEE Transactions on Computational Biology and Bioinformatics*, 2008. To appear. LBNL-6377.

17. Cecilia Aragon, Stephen Bailey, Sarah Poon, Karl Runge, and Rollin Thomas. Sunfall: A Collaborative Visual Analytics System for Astrophysics. *Journal of Physics Conference Series – SciDAC 2008*, 125, June 2008. LBNL-657E.

18. C. C. Fowlkes, C. L. Luengo Hendriks, S. V. E. Keränen, G. H. Weber, O. Rübel, M.-Y. Huang, S. Chatoor, A. H. DePace, L. Simirenko, C. Henriquez, A. Beaton, R. Weiszmann, S. Celniker, B. Hamann, D. W. Knowles, M. D. Biggin, M. B. Eisen, and J. Malik. A Quantitative Spatio-temporal Atlas of Gene Expression in the Drosophila Blastoderm. *Cell*, 133:364–374, April 2008.

19. Brian Paul, Sean Ahern, E. Wes Bethel, Eric Brugger, Rich Cook, Jamison Daniel, Ken Lewis, Jens Owen, and Dale Southard. Chromium Renderserver: Scalable and Open Remote Rendering Infrastructure. *IEEE Transactions on Visualization and Computer Graphics*, 14(3), May/June 2008. LBNL-63693.

20. John C. Anderson, Christoph Garth, Mark A. Duchaineau, and Kenneth I. Joy. Discrete Multi-Material Interface Reconstruction for Volume Fraction Data. *Computer Graphics Forum (Proc. of Eurographics/IEEE-VGTC Symposium on Visualization 2008)*, 27(3):1015–1022, 2008.

21. Christoph Garth, Xavier Trichoche, and Kenneth I. Joy. Lagrangian Visualization of Flow-Embedded Surface Structures. *Computer Graphics Forum (Proc. of Eurographics/IEEE-VGTC Symposium on Visualization 2008)*, 27(3):767–774, 2008.

22. R. Westermann K. Buerger, J. Krueger. Direct Volume Editing. *IEEE Transactions on Visualization and Computer Graphics (Special Issue: Proceedings of IEEE Visualization 2008)*, 14(6), November/December 2008.

23. M. Chen, M. Kirby, C. Hansen, and T. Moller. A Staggered Grid for Multi-resolution Volume Rendering. *Computer Graphics Forum Journal*, Accepted, to appear.

24. Aaron Knoll, Younis Hijazi, Charles Hansen, Ingo Wald, and Hans Hagen. Interactive Ray Tracing of Arbitrary Implicit Functions. *Computer Graphics Forum Journal*, Accepted, to appear.

25. Aaron Knoll, Ingo Wald, and Charles Hansen. Coherent Multiresolution Isosurface Ray Tracing. *The Visual Computer*, 2008. To Appear.

26. Guo-Shi Li, Charles Hansen, and Xavier Tricoche. Physically-based Dye Advection for Flow Visualization. *Computer Graphics Forum Journal*, 27(3):727–734, 2008.

27. Guo-Shi Li, Xavier Tricoche, Daniel Weiskopf, and Charles Hansen. Flow Charts: Visualization of Vector Fields on Arbitrary Surfaces. *IEEE Transactions on Visualization and Computer Graphics*, 14(5):1067–1080, 2008.

28. Jens Bellmann, Frank Michel, Eduard Deines, Martin Hering-Bertram, Jan Mohring, and Hans Hagen. Sound Tracing: Rendering Listener Specific Acoustic Room Properties. *Computer Graphics Forum*, 27(3):943–950, 2008.

5.1.2 Conference Proceedings

1. Oliver Rübel, Prabhat, Kesheng Wu, Hank Childs, Jeremy Meredith, Cameron G. R. Geddes, Estelle Cormier-Michel, Sean Ahern, Gunther H. Weber, Peter Messmer, Hans Hagen, Bernd Hamann, and E. Wes Bethel. High Performance Multivariate Visual Data Exploration for Extemely Large Data. In *SuperComputing 2008 (SC08)*, Austin, Texas, USA, November 2008. LBNL-716E (to appear).

2. Daniela M. Ushizima, Oliver Rübel, Prabhat, Gunther H. Weber, E. Wes Bethel, Cecilia R. Aragon, Cameron G.R. Geddes, Estelle Cormier-Michel, and Bernd Hamann. Automated Analysis for Detecting Beams in Simulations. In *Proceedings of the Seventh International Conference on Machine Learning and Applications*, December 2008. LBNL-960E.

3. H. Wang, C. E. Scheidegger, and C. Silva. Optimal Bandwidth Selection for MLS Surfaces. In *IEEE International Conference on Shape Modeling and Applications (SMI) 2008*, 2008.

4. E. Santos, L. Lins, J. P. Ahrens, J. Freire, and C. Silva. A First Study on Clustering Collections of Workflow Graphs. In *Second International Provenance and Annotation Workshop (IPAW 2008)*, 2008.

5. S. P. Callahan, J. Freire, C. E. Scheidegger, C. Silva, and Huy T. Vo. Towards Provenance-Enabling ParaView. In *Second International Provenance and Annotation Workshop (IPAW 2008)*, 2008.

6. T. Ellkvist, D. Koop, E. W. Anderson, J. Freire, and C. Silva. Using Provenance to Support Real-Time Collaborative Design of Workflows. In *Second International Provenance and Annotation Workshop (IPAW 2008)*, 2008.

7. L. Lins, D. Koop, E. W. Anderson, S. P. Callahan, E. Santos, C. E. Scheidegger, J. Freire, and C. T. Silva. Examining Statistics of Workflow Evolution Provenance: A First Study. In *Statistical and Scientific Database Management (SSDBM) 2008*, 2008.

8. C. E. Scheidegger, H. T. Vo, D. Koop, J. Freire, and C. Silva. Querying and Re-Using Workflows with VisTrails. In *ACM SIGMOD 2008*, 2008.

9. J. Freire and C. Silva. Towards Enabling Social Analysis of Scientific Data. In *CHI Social Data Analysis Workshop 2008*, 2008.

10. Cecilia Aragon, Sarah Poon, Gregory Aldering, Rollin Thomas, and Robert Quimby. Using Visual Analytics to Maintain Situational Awareness in Astrophysics. In *Proceedings of 2008 IEEE Symposium on Visual Analytics Science and Technology*. IEEE Computer Society Press, October 2008. LBNL-658E.

11. Gunther H. Weber, Vincent E. Beckner, Hank Childs, Terry J. Ligocki, Mark Miller, Brian van Straalen, and E. Wes Bethel. Visualization of Scalar Adaptive Mesh Refinement Data. 385:309–320, 2008. LBNL-220E.

12. David Pugmire, Hank Childs, and Sean Ahern. Parallel Analysis and Visualization on Cray Compute Node Linux. In *Cray Users Group Meeting*, Helsinki Finland, May 2008.

13. K. Potter, J. Krueger, and C.R. Johnson. Towards the Visualization of Multi-Dimensional Stochastic Distribution Data. In *Proceedings of The International Conference on Computer Graphics and Visualization (IADIS) 2008*, 2008.

5.1.3 Invited Articles

1. C. Silva and J. Freire. Software Infrastructure for Exploratory Visualization and Data Analysis: Past, Present and Future. In *Journal of Physics: Conference Series (SciDAC 2008 Conference)*, 2008.

2. E. Wes Bethel, Chris Johnson, Charles Hansen, Claudio Silva, Steven Parker, Allen Sanderson, Lee Myers, Martin Cole, Xavier Tricoche, Sean Ahern, George Ostrouchov, Dave Pugmire, Jamison Daniel, Jeremy Meredith, Valerio Pascucci, Hank Childs, Peer-Timo Bremer, Ajith Mascarenhas, Ken Joy, Bernd Hamann, Christoph Garth, Cecilia Aragon, Gunther Weber, and Prabhat. Seeing the Unseeable. *SciDAC Review*, (8):24–33, Summer 2008. LBNL-472E.

3. Oliver Rübel, Gunther H. Weber, Min-Yu Huang, E. Wes Bethel, Soile V. E. Keränen, Charless C. Fowlkes, Cris L. Luengo Hendriks, Angela H. DePace, Lisa. Simirenko, Michael B. Eisen, Mark D. Biggin, Hans Hagen, Jitendra Malik, David W. Knowles, and Bernd Hamann. *PointCloudXplore 2: Visual Exploration of 3D Gene Expression*. GI Lecture Notes in Informatics. Gesellschaft fuer Informatik (GI), 2008. LBNL-249E.

5.1.4 Book Chapters

1. E. Wes Bethel, Hank Childs, Ajith Mascarenhas, Valerio Pascucci, and Prabhat. Scientific Data Managment Challenges in High Performance Visual Data Analysis. In Arie Shoshani and Doron Rotem, editors, *Scientific Data Management: Challenges, Existing Technology, and Deployment*. Chapman & Hall/CRC Press, 2008. (to appear).

5.1.5 Posters

1. Oliver Rübel, Prabhat, Kesheng Wu, Hank Childs, Jeremy Meredith, Cameron G. R. Geddes, Estelle Cormier-Michel, Sean Ahern, Gunther H. Weber, Peter Messmer, Hans Hagen, Bernd

Hamann, and E. Wes Bethel. Application of High-performance Visual Analysis Methods to Laser Wakefield Particle Acceleration Data. In *IEEE Visualization 2008*, Columbus, Ohio, USA, October 2008. (LBNL report number pending) (to appear).

2. E. Wes Bethel, C.R. Johnson, C. Aragon, Prabhat, O. Rübel, G. Weber, V. Pascucci, H. Childs, P.-T. Bremer, A. Mascarenhas, B. Whitlock, S. Ahern, J. Meredith, G. Ostrouchov, K. Joy, B. Hamann, C. Garth, M. Cole, C. Hansen, S. Parker, A. Sanderson, C.T. Silva, and X. Tricoche. DOE SciDAC Visualization and Analytics Center for Enabling Technologies. In *2008 DOE ASCR CS PI Meeting*, Denver, CO, USA, April 2008.

5.1.6 Technical Reports

1. Luke J. Gosink, Kesheng Wu, E. Wes Bethel, John D. Owens, and Kenneth I. Joy. Bin-Hash Indexing: A Parallel Method for Fast Query Processing. Technical Report LBNL-729E, Lawrence Berkeley National Laboratory, Berkeley, CA, USA, 94720, 2008.

5.1.7 Recently Submitted Publications

1. K. Potter, J. Kniss, R. Riesenfeld, and C. Johnson. Visualizing Summary Statistics and Uncertainty. *IEEE Transactions on Visualization and Computer Graphics*, 2008. Fast-tracked from IEEE VIS submission.

5.2 Presentations

5.2.1 Invited Presentations

1. E. Wes Bethel. High Performance, Query-Driven Scientific Visualization: Finding Smaller Needles in Larger Haystacks. In *University of Tulsa Research Seminar*, Tulsa, OK, USA, September 2008.

2. E. Wes Bethel. Parallelism in Graphics and Visualization. In *University of Tulsa, CS6813 Guest Lecture*, Tulsa, OK, USA, September 2008.

3. E. Wes Bethel. Accelerating Visual Knowledge Discovery with Query-Driven Visualization. In *SIAM Conference on Imaging Science (IS08), Visualization and Analytics for Science Discovery*, San Diego, CA, USA, July 2008.

4. E. Wes Bethel. Scientific Visualization: The Modern Oscilloscope for Seeing the Unseeable. In *LBNL Summer Lecture Series*, Berkeley, CA, USA, June 2008. Also on YouTube at `http://www.youtube.com/watch?v=R4LLuEOHTtE`.

5. E. Wes Bethel. Modern Scientific Visualization is More Than Just Pretty Pictures. In *Numerical Modeling of Space Plasma Flows: Astronum-2008 (Astronomical Society of the Pacific Conference Series)*, St. John, USVI, June 2008.

6. Gunther H. Weber. Visualization and Analysis of Adaptive Mesh Refinement Data with VisIt. In *Numerical Modeling of Space Plasma Flows: Astronum-2008 (Astronomical Society of the Pacific Conference Series)*, St. John, USVI, June 2008.

7. E. Wes Bethel. Visual Data Analysis and Data Exploration at the Extreme Scale. In *DOE Office of Science, Advanced Scientific Computing Research Principal Investigator Meeting*, Denver, CO, USA, April 2008.

8. Hank Childs. Why Petascale Visualization Will Change the Rules. In *International Conference on Computational Science 2008 (ICCS 2008)*, Krakow, Poland, June 2008. Keynote Presentation.

9. Hank Childs. Why Petascale Visualization Will Change the Rules. In *Center for Scalable Application Development Software (CScADS) Summer Workshop on Scientific Data Analysis and Visualization for Petascale Computing*, Snowbird, Utah, USA, July 2008.

10. Hank Childs. Petascale Visualization and VisIt. In *Colloquium Series for the Center for Computation and Technology (CCT) at Louisiana State University*, Baton Rouge, LA, USA, September 2008.

11. Gunther H. Weber. Visualization Tools for Adaptive Mesh Refinement Data. In *DOE Computer Graphics Forum*, Duck, NC, USA, April 2008.

12. David Pugmire, Hank Childs, and Sean Ahern. Parallel Analysis and Visualization on Cray Compute Node Linux. In *DOE Computer Graphics Forum*, Duck, NC, USA, April 2008.

13. Charles Hansen. Multidimensional Transfer Functions and other GPU Methods. In *Exxon-Mobile*, Houston, TX, USA, August 2008.

14. Claudio Silva. Unstructured Grids and High-Quality Surface Reconstruction from Different Data Types. In *Exxon-Mobile*, Houston, TX, USA, August 2008.

15. Claudio Silva. VisTrails: Provenance and Data Exploration. In *National Biomedical Computation Resource (NBCR) Summer Institute*, San Diego, CA USA, August 2008.

16. Claudio Silva. Software Infrastructure for Exploratory Visualization and Data Analysis: Past, Present and Future. In *SciDAC 2008*, Seattle, WA USA, July 2008.

17. Charles Hansen. Interactive Texture-based Flow Visualization. In *LANL*, Los Alamos, NM, USA, August 2008.

18. Charles Hansen. CSAFE. In *University of Kaiserslautern Colloquium*, Kaiserslautern, GERMANY, May 2008.

19. George Ostrouchov. Data-Parallel Analysis and Graphics with R. In *DOE Computer Graphics Forum*, Duck, NC, USA, April 2008.

20. George Ostrouchov. Stalking the Interactive Terabyte with R: Data-Parallel Statistical Computing. In *University of Tennessee SOMS Seminar Series*, Knoxville, TN, USA, April 2008.

5.3 Tutorials

5.3.1 VisIt Tutorials

1. SciDAC 2008 Program Meeting, June 2008, Seattle WA. Presenters: Hank Childs and Sean Ahern. Approximately 20 attendees.

2. CScADS workshop, July 2008, Snowbird Utah. Presenters: Hank Childs and Jeremy Meredith. Approximately 20 attendees.

3. Princeton Plasma Physics Laboratory, September 2008. Presenter: Sean Ahern. Approximately 20 attendees.

5.3.2 VisTrails Tutorials

1. SciDAC 2008 Program Meeting, June 2008, Seattle WA. Presenters: Claudio Silva and Carlos Scheidegger. Approximately 20 attendees.

2. CScADS workshop, July 2008, Snowbird Utah. Presenter: Claudio Silva. Approximately 20 attendees.

Figure 9: Sean Ahern delivers a VisIt tutorial to fusion researchers at the Princeton Plasma Physics Laboratory in September 2008.

5.4 Workshops

1. SciDAC Framework Application for Core-Edge Transport Simulations (FACETS) Fall 2008 Program meeting. September 4-5, 2008. Dave Pugmire, Allen Sanderson.

2. Center for Scalable Application Development Software (CScADS) workshop on Scientific Data Analysis and Visualization for Petascale Computing. Hank Childs, Jeremy Meredith.

3. Office of Nuclear Energy's NEAMS program (Nuclear Energy Advanced Modeling and Simulation) Workshop on Enabling Technologies. Hank Childs, Wes Bethel. Childs chaired breakout session on results.

4. DoE Mathematics for the Analysis of Petascale Data Workshop (MAPD). Kenneth I. Joy and Valerio Pascucci.

5. Third Annual Workshop of the International Research Training Group (IRTG). Kaiserslautern, September 29 - November 1, 2008. Participants: Kenneth I. Joy, Christoph Garth, and Eduard Deines.

5.5 Awards

1. Best Paper Award. Optimal Bandwidth Selection for MLS Surfaces. H. Wang, C. E. Scheidegger, and C. Silva. IEEE International Conference on Shape Modeling and Applications (SMI) 2008..

2. SciDAC 2008 OASCARS. VACET researchers win three "People's Choice Awards" at Visualization Night at the SciDAC 2008 Program meeting in Seattle WA in June 2008, as well as one "Honorable Mention. These are listed and described in more detail here: `http://www.vacet.org/news/news2008.html#scidac`. See Figure 10.

3. Stakeholders win OASCARS at SciDAC 2008. VACET science stakeholders at Tech-X Corporation win an OASCAR at the SciDAC 2008 meeting using VACET software to show off their VORPAL code, which is used in high energy physics and fusion applications.

5.6 Service

5.6.1 Technical Reviewer

1. IEEE Transactions on Visualization and Computer Graphics. Associate Editor: V. Pascucci. Technical Paper Reviewer: Wes Bethel, Gunther H. Weber. Kenneth I. Joy, Peer-Timo Bremer, Jens Krüger, Kristi Potter, Charles Hansen, Valerio Pascucci, Christoph Garth.

2. IEEE Visualization 2008. Technical Paper Reviewer: Wes Bethel, Hank Childs, Gunther H. Weber, Kenneth I. Joy, Peer-Timo Bremer, Jens Krüger, Kristi Potter, Valerio Pascucci, Christoph Garth.

3. IEEE VAST 2008. Technical paper reviewer: Gunther H. Weber.

4. DOE SBIR/STTR Technical Proposal Reviewer: E. Wes Bethel.

5. Journal of Systems and Software: Gunther H. Weber.

6. ACM Transactions on Graphics. Technical Paper Reviewers: Peer-Timo Bremer, Jens Krüger, Valerio Pascucci.

5.6.2 Program Committee

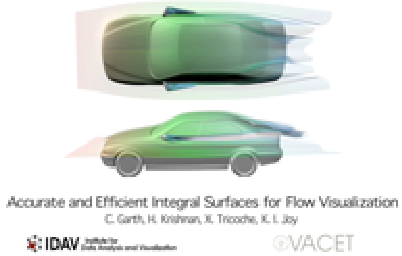
1. ACM Multimedia 2008 Technical Demonstrations: Claudio Silva.

2. Knowledge-Assisted Visualization (KAV) 2008: Claudio Silva.

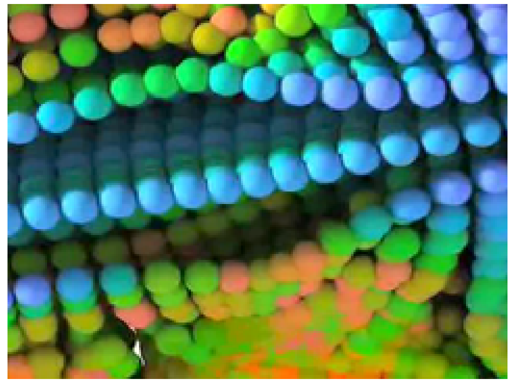
3. International Symposium on Volume Graphics 2008 (VG08): Claudio Silva.

4. XIX Brazilian Symp on Computer Graphics and Image Processing (SIBGRAPI) 2008: Claudio Silva.

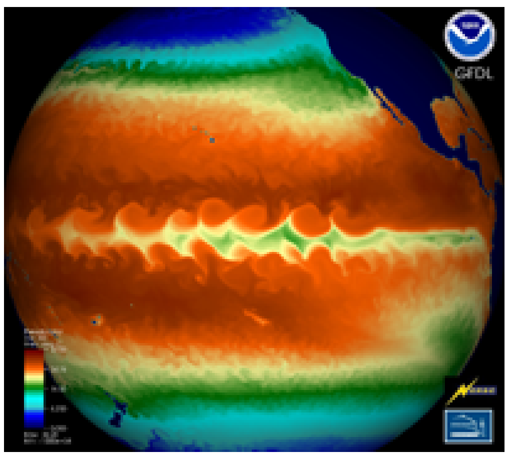
5. Symposium on 3D Data Processing, Visualization, and Transmission (3DPVT) 2008: Claudio Silva.



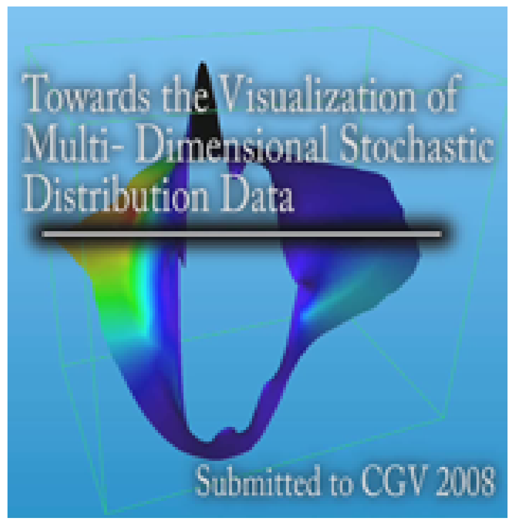
(a) Accurate and Efficient Integral Surfaces for Flow Visualization. C. Garth, H. Krishnana, X. Tricoche, and K. Joy.



(b) The Golden Age of Scientific Visualization. C. Johnson et al.



(c) Visualization of Next-generation GFDL/NOAA Climate Simulations. Prabhat, J. Jacobsen, G. Weber, C. Kerr, V. Balaji, W. Bethel..



(d) Towards the Visualization of Multi-Dimensional Stochastic Distribution Data. K. Potter, J. Krüger, C. Johnson.

Figure 10: VACET researchers with three "People's Choice Awards" and one "honorable mention" at Visualization Night at the SciDAC 2008 Program meeting in Seattle, WA.

6. 2nd International Provenance and Annotation Workshop (IPAW 2008): Claudio Silva.
7. ACM SIGGRAPH 2008 Papers Program: Claudio Silva.
8. ACM Solid and Physical Modeling Symposium (SPM) 2008: Claudio Silva.
9. IEEE International Conference on Shape Modeling and Applications (SMI) 2008: Claudio Silva.
10. EuroVis 2008: Claudio Silva.
11. International Conference on Computer Animation and Social Agents (CASA) 2008: Claudio Silva.
12. Symposium on Geometry Processing 2008: Claudio Silva.

13. Symposium on Computational Geometry 2009. General Conference co-Chair: V. Pascucci.

14. IEEE/Eurographics International Symposium on Volume Graphics 2008. General Conference co-Chair: V. Pascucci.

15. SIAM invited minisymposium on "Visualization and Analytics for Science Discovery¡i¿ (at the SIAM Annual Meeting, 2008). Chair: V. Pascucci.

16. SIAM Conference on Data Mining 2008: George Ostrouchov.

17. DOECGF Steering Committee: Wes Bethel and Sean Ahern.

18. IEEE Workshop Knowledge-assisted Visualization: Gunther H. Weber.

19. TopoInVis 2009. Organization Committee: Valerio Pascucci; Program Committee: Peer-Timo Bremer, Gunther H. Weber, Charles Hansen, and Christoph Garth.

20. IEEE Visualization 2008. Papers Co-Chair: Charles Hansen. General Conference co-Chair: Kenneth I. Joy. Exhibits Chair: Kenneth I. Joy. Papers Committee: Kenneth I. Joy.

21. Information and Knowledge Sciences Review Committee, Los Alamos National Laboratory: Kenneth I. Joy.

22. EUROVIS 2008: European Visualization Conference 2008: Kenneth I. Joy and Charles Hansen.

23. EUROGRAPHICS 2009. General Areas co-Chair: Jens Krüger. Program Committee: V. Pascucci.

24. Eurographics 2008 Symposium on Parallel Graphics and Visualization (EGPGV '08): Charles Hansen and Valerio Pascucci.

25. Joint Statistical Meetings 2010. Elected Program Chair for section on Physical and Engineering Sciences: George Ostrouchov.